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OPERATION OF THE OPTICALLY PUMPED POLARIZED H^- ION SOURCE AT LAMPF

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Abstract

We report on the first five months of operation of the Optically Pumped Polarized Ion Source (OPPIS) for the nuclear physics research program at LAMPF. The LAMPF OPPIS is unique in using Ti:Sapphire lasers to polarise the potassium charge-exchange medium, and until recently was unique in using a superconducting magnet in the ECR source and polariser regions. The ECR extraction electrode biasing arrangement is also unique. Typical performance was 25 microamps of peak current (measured at 750 keV) with 55% beam polarisation or 15 microamps at 62%. Ion source availability was greater than 90%. We also report our planned improvements in preparation for research operation in May of 1991.

1 Introduction

In its first year of operation, OPPIS exceeded its design goal by producing a polarised beam whose value of P^2I was more than a factor of 10 greater than that of the Lamb-shift source. The source was operated for up to 500 hrs between maintenance periods. The 25-μA peak current results in a 600-nA average beam current in the experimental area at 6% duty with 100-nS chopping for neutron-spin interaction experiments.

Full descriptions of optically pumped ion sources can be found in the literature.[1] A drawing of OPPIS at LAMPF is shown in Figure 1. This ion source has several unique features, both in its H^- source and its optical pumping system.

2 Features of LAMPF OPPIS

The OPPIS ECR source operates at a frequency of 18 GHz and a power level of 1 kW. The axial magnetic field of the ECR and the polariser cell is provided by a superconducting magnet with a 14 cm bore. This large bore allows for vacuum pumping between the ECR extraction lenses and the polariser cell, minimising the unpolarised H^0 beam formed from residual hydrogen gas.

The ECR extraction system consists of three multiaperture lenses. The electrodes are biased in the "accel-accel" configuration [2] to produce a low divergence H^+ beam.

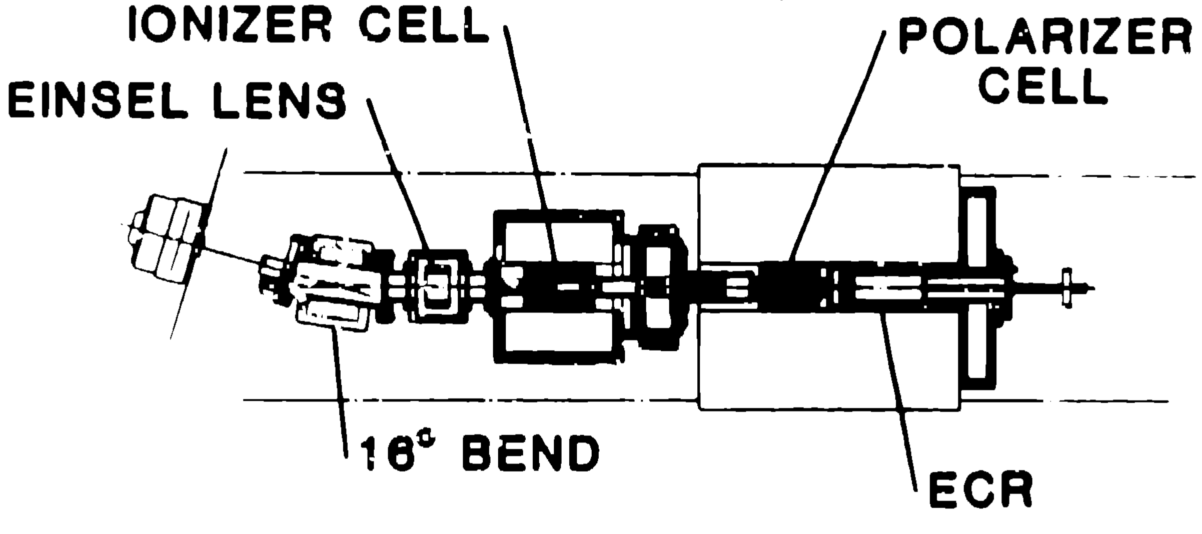

Figure 1: A diagram of OPPIS. A profile of the axial magnetic field in the source overlays the diagram.

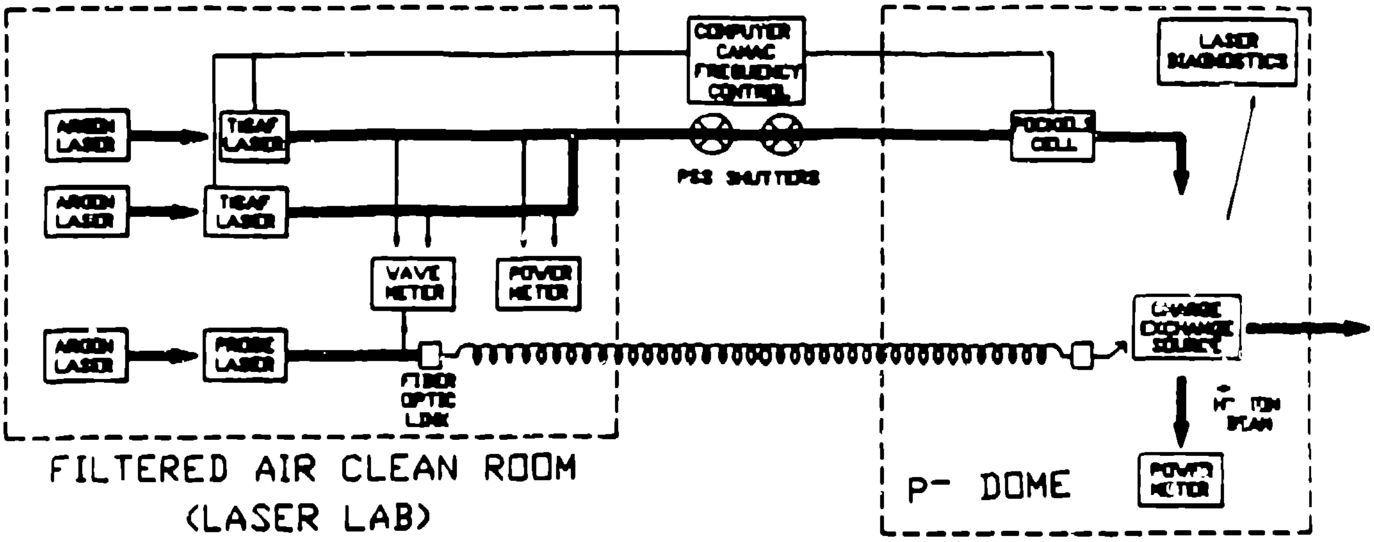

Figure 2: A schematic of the optical pumping system of LAMPF OPPIS.

For the 1990 operating period, lenses of 1-mm thickness and 1-mm spacing and a hexagonal close-packed array of 37 or 19 1-mm diameter holes with 0.25 mm web between holes were used. The lens configuration has since been further optimised; details of these experiments are given later in this paper.

A schematic of the optical pumping system of OPPIS is given in Figure 2. LAMPF was the first facility to use K rather than Na in the polariser cell. Potassium can be optically pumped by the solid-state Ti::sapphire laser. These lasers can produce over 3 W of light with a bandwidth of ≈500 MHz, which efficiently pumps the 1.3 GHz bandwidth of K. This large laser power makes it possible to maintain high polarisation while dedicating a single laser to a particular spin state, simplifying the spin-flip procedure greatly and allowing rapid spin flip. The Ti::sapphire lasers have stable frequency and power. Their reliability contributed to the high availability of polarised beam.

As shown in Fig. 1, the OPPIS 4-keV beamline has a 16° bend before the beam is injected into the 750-kV high voltage column. This feature allows for efficient insertion of the laser beam and avoids depositing the high-intensity neutral hydrogen beam and alkali vapor in the high voltage column. This bend is accomplished by combined electric and magnetic fields balanced to give no net spin precession with respect to the particle direction of motion. This allows a longitudinally polarised beam to be injected into the 750-keV spin precession system, which gives the experimental areas complete freedom of spin orientation. Since the spin precession is proportional to the anomalous part of the particle gyromagnetic ratio, which for H^- ions is −3.78, the spin correction device has a magnetic field to give a 4.2° left bend and electric field to give approximately a 20.2° right bend for net bend of 16°. The effective field length on axis is 104 mm. The fields have the typical $E \times B$ or Wien filter geometry in a very compact space, so the device is termed the "Teeny Wieny filter." The Teeny Wieny filter accomplishes the 16° bend and spin precession correction with no measurable loss of beam intensity.

3 Development Experiments

One of the reasons for the successful performance level of OPPIS is the change from a accel-decel to an accel-accel extraction system. The accel-accel mode produces an H^- current density that is seven times that of the accel-decel mode [2]. Since the end of the LAMPF experiment run cycle in October 1990, experiments to further optimise the ECR extraction lenses have been performed. When the extraction lenses are operated in the accel-accel mode and the net extraction voltage is lowered, we believe the plasma sheath becomes less concave, resulting in a more parallel H^+ beam. This parallel H^+ beam produces a less divergent H^0 beam which better matches the small acceptance angle of the ioniser cell (10 mrad).

In addition to the extraction voltage, an important parameter determining the divergence angle of the H^+ beam is the spacing between the first two lenses. Data exploring the effect of this spacing as a function of extraction voltage is shown in Fig. 3. The data shows that for 2-mm spacing the accel-accel effect is not evident. For the 0.5-mm spacing, significant beam heating of the K cell was observed, so this data was taken with a 0.5-cm diameter beam for comparison. The optimum spacing for 1-mm holes and 1-mm thickness seems to be 1 mm.

Another important parameter for the H^+ beam quality is aspect ratio, where aspect ratio is defined as the ratio of a single extraction hole diameter to lens thickness. Studies indicate that the accel-accel mode does not work well for aspect ratio greater than 1.0. The data shown in Fig. 4 indicates that an aspect ratio of 0.75 is 20% better than that of 1.0.

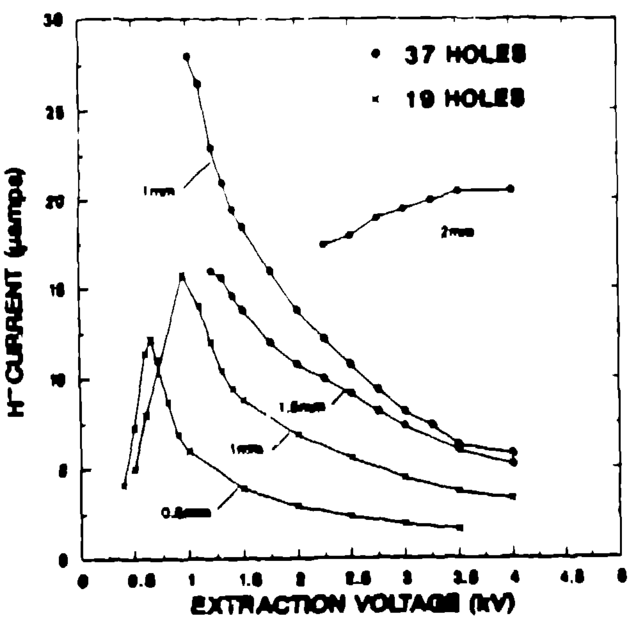

Figure 3: H^- current versus the extraction voltage for different spacings between the first two lenses.

Because some of the nuclear physics experiments at LAMPF have limited current tolerance, which enhances the beam polarisation requirement, considerable effort has been concentrated on improving polarisation. The K cell diameter is 0.8 cm and the H^+ beam, with 37 holes in a close-packed hexagonal pattern, has a flat-to-flat diameter of 0.7 cm. When the H^+ extraction geometry is changed to a 19-hole pattern with a beam diameter of 0.5 cm, and half the extraction area, the H^- beam polarisation increases from 55% to 62%. Two effects contribute to this improvement. Lowering the extraction area reduces the required hydrogen flow, thus limiting the unpolarised beam formed

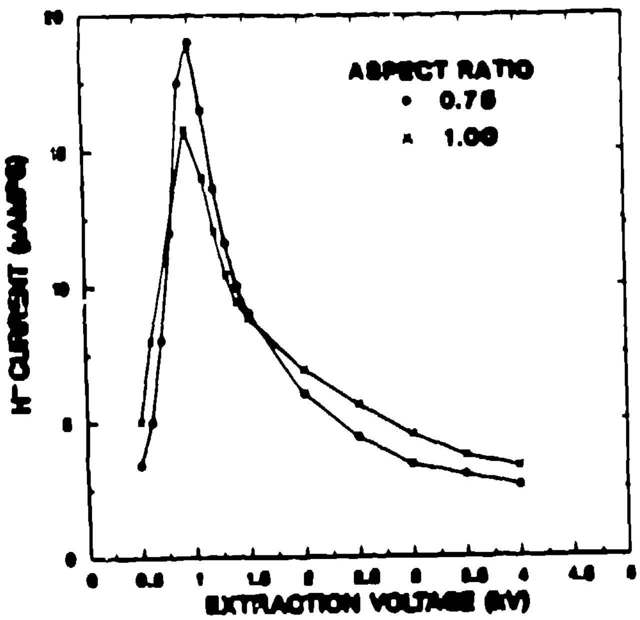

Figure 4: H^- current versus extraction voltage for extraction lens aspect ratios of 1.0 and 0.75.

from residual gas. Also, there is a radial dependence of K polarisation in the polariser target due to insufficient laser coverage and depolarising wall collisions. Thus, a smaller diameter H^+ beam selects only the more polarised portion of the K target. The improvement in beam polarisation is probably a combination of these effects.

The dependence of beam polarisation on the magnetic field strength in the Na ioniser cell was explored. Increasing the solenoidal magnetic field strength from 1500 g to 2000 g increases the beam relative polarisation 3%, but decreases the beam current 25%. The decrease in beam current is due to the increased emittance of the H^- beam [3].

Another enhancement of beam polarisation was achieved by tuning both Ti::sapphire lasers to pump a single spin state. This not only doubles the available laser power but also improves the spacial and frequency coverage of the K vapor. This results in a relative improvement in beam polarisation of 8%. Using this effect, increasing the magnetic field in the ioniser solenoid to 2000 g, and using a 0.5 cm H^+ beam yields 13 μA with beam polarisation of 70%. Work is currently in progress to develop an automated laser frequency adjustment, to allow spin flipping with both lasers tuned to each spin state. Progress in this endeavor is reported by Swenson, *et al.* at this conference.

Conclusion

The performance of OPPIS has enhanced the LAMPF neutron-spin interaction program. Development efforts are focussed to improve the beam polarisation to better satisfy the full range of nuclear spin experiments. The performance level goal for 1991 is 20 μA at 60% polarisation.

References

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